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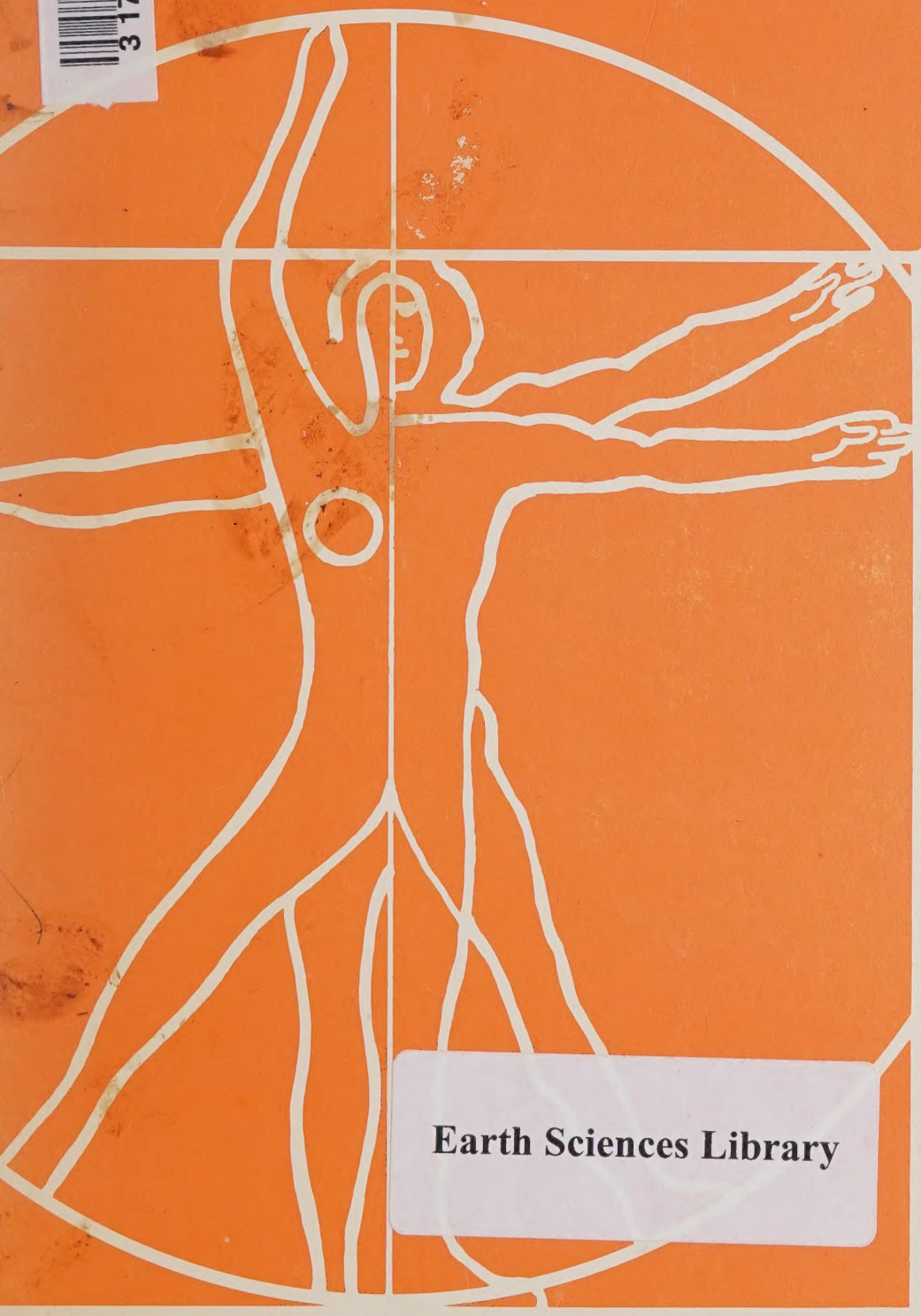
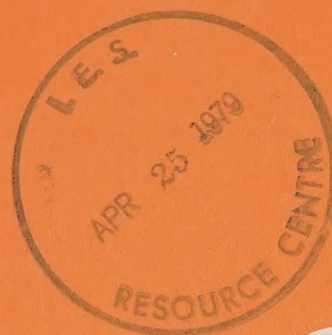
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SWIMMING POOL WATER QUALITY

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SUMMARY

A study was made of the human-health aspects of swimming pool water quality in Canada. The diseases which have most frequently been associated with the use of swimming pools include eye, ear, nose, and throat infections, skin infections, and enteric maladies. The microorganisms causing these infections are mainly derived from swimmers themselves as well as land runoff or industrial wastes; these organisms may persist in pool water due to improper operation. Pool water must be filtered and disinfected and the entire area must be kept clean in order to ensure minimal risk of infection. The current provincial regulations for swimming pools and their operation were reviewed. The regulations generally specify water quality, clarity, temperature, circulation, and disinfection, as well as the limits of bacteriological contamination. It is concluded that total coliform and total viable bacteria counts are inadequate indicators of swimming pool water quality, and should be supported with, or replaced by, measurement of Staphylococcus aureus, Pseudomonas aeruginosa, total staphylococci, and fecal streptococci. Staphylococcus aureus and Pseudomonas aeruginosa should not be present in 100 mL samples. In addition, in 90 percent of all samples the total staphylococci should be less than 25 per 100 mL and not exceed 100 per 100 mL in any one sample. Most probable number techniques are presently preferred to membrane filtration methods for enumeration of chlorine-stressed organisms.

This document was prepared from a report submitted under contract by the Canadian Public Health Association by Dr. R.S. Tobin and Miss E. Dashney of the Bureau of Chemical Hazards.

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RÉSUMÉ

Une étude portant sur la qualité de l'eau dans les piscines et la santé a été effectuée au Canada. Parmi les maladies qui ont été le plus souvent liées à l'utilisation des piscines figurent les infections des yeux, des oreilles, du nez et de la gorge, les infections cutanées et les maladies entériques. Les microorganismes responsables de ces infections proviennent principalement des nageurs eux-mêmes, mais aussi du sol ou des déchets industriels; ces microorganismes peuvent survivre dans l'eau de piscine lorsque la piscine est mal entretenue. L'eau doit être filtrée et désinfectée et tout le périmètre doit être gardé propre afin de minimiser les risques d'infection. Les règlements provinciaux actuels relatifs aux piscines et à leur entretien ont été étudiés. En général, les règlements intéressent la qualité, la clarté, la température, la circulation et la désinfection de l'eau ainsi que les limites de contamination bactériologique. Nous sommes arrivés à la conclusion que la numération des coliformes totaux et des bactéries viables totales ne constitue pas un indicateur satisfaisant de la qualité de l'eau dans les piscines et que ces méthodes doivent être complétées, ou remplacées, par la détermination de Staphylococcus aureus, de Pseudomonas aeruginosa, des staphylocoques totaux et des streptocoques fécaux. On ne devrait pas déceler la présence de Staphylococcus aureus et de Pseudomonas aeruginosa dans des échantillons de 100 mL. De plus, le nombre total de staphylocoques devrait être inférieur à 25 par 100 mL dans 90 pour cent des échantillons et aucun échantillon ne devrait contenir plus de 100 staphylocoques par 100 mL. Par ailleurs, les techniques du nombre le plus probable sont actuellement préférables aux méthodes de filtration sur membranes pour la numération des microorganismes lésés par le chlore.

Ce document a été rédigé par le D^r R.S. Tobin et par M^{lle} E. Dashney du Bureau des dangers des produits chimiques à partir d'un rapport préparé en vertu d'un contrat par l'Association canadienne d'hygiène publique.

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INTRODUCTION

The ruins of the oldest swimming pool known, in India, have been dated at approximately 3000 B.C. Ancient Greece, Egypt, and Rome had large pools for athletic events and for recreational purposes. It was only in the restrained moral climate of the Middle Ages that the use of public baths declined. Today, swimming pools provide a significant form of recreation in Canadian communities. There has been a pronounced increase in the demand both for indoor and outdoor pools because of limited access and pollution of natural bathing areas. Large public pools have been built as community projects, and smaller wading pools have been placed in many parks for pre-school children. It is necessary, however, to safeguard the health of those using swimming pools, and to prevent the transmission of disease from one user to another. At present, most countries have established national standards or guidelines of water quality for swimming pools.

A swimming pool, whether indoor or outdoor, may be defined as any structure containing an "artificial body of water" to which the public has access for bathing purposes.

The objectives of this study were to review the following subject areas:

1. the diseases associated with water in swimming pools;
2. the sources of pollution;
3. the indicators used or suggested to test the bacteriological quality of water in them;
4. treatment applied to swimming-pool water;
5. current standards in Canada regulating water quality in swimming pools;
6. recommendations.

Diseases associated with swimming-pool water

A survey of the literature reveals that as early as the 1900's swimming-pool water was considered a vehicle for disease. Reviews and correspondence by Manheimer (1) in 1914, by Lloyd (2) in 1921, and by Levine (3) in 1916 stressed the role of swimming pools in producing upper respiratory disease, conjunctivitis, otitis and skin infections. Forbes suggested an association between intestinal diseases and swimming pools in 1927 (4) and they have received ever-increasing attention since then. The role of swimming pools as sources of disease probably has been somewhat overestimated; unfortunately, there are no good epidemiological studies

on this subject. The causative agents of diseases transmitted by swimming-pool water are mainly bacteria and viruses that inhabit the human skin and upper respiratory, urinary, and intestinal tracts. We must also consider fungi and a few protozoa and helminths.

The diseases associated with swimming pools are:

- (a) ear, eye, nose, and throat infections;
- (b) skin infections;
- (c) enteric and other infections.

(a) Ear, eye, nose and throat infections

These infections represent more than 50 % of all illnesses in swimmers (5). Otitis or "earaches" are commonly encountered during the summer months (6) and some authors have suggested a relationship between swimming and ear infections (5, 7). Pseudomonas aeruginosa has been associated with these infections (5, 8). This bacterium is not a normal inhabitant of the healthy ear (8, 9). Hoadley and Knight (10) have recently demonstrated that swimming increases the risk of P. aeruginosa otitis externa, and that outer-ear infections tend to be more frequent and severe among swimmers than among non-swimmers.

Pharyngoconjunctival fever, characterized by high fever, sore and inflamed throat, headache, and follicular conjunctivitis, has affected many people who frequent swimming pools. Outbreaks were reported in Washington in 1954 (11), in Toronto in 1955 and 1957 (12), and in the Netherlands in 1958 (13). These were attributed to Adenovirus 3, Adenovirus 7, and Coxsackie A16 virus, respectively. The viruses were recovered from throat and eye swabs of the patients. Coxsackie and parainfluenza viruses have been isolated from pools by Brown et al. (14).

It has been suggested that the presence of Staphylococcus and of Streptococcus in swimming-pool water could result from nasal secretions. If this is so, other pathogenic organisms such as Corynebacterium diphtheriae, the causative agent of tonsillar, nasopharyngeal, and laryngeal diphtheria, could also be present in the water.

(b) Skin infections

Several outbreaks of skin rash associated with the use of motel whirlpool baths have been reported in the United States in the past six years (15-17). In these outbreaks, the rash appeared one or two days after exposure and resolved itself within a week. The rash was

reported only by the guests who used the pool. Pseudomonas aeruginosa serogroup 11 was isolated from the skin lesions of bathers and from the pools; however, P. aeruginosa was not unequivocally implicated as the aetiological agent.

Mycobacterium marinum, also referred to as M. balnei, has been isolated from pool water. It is an atypical Mycobacterium known to cause "swimming-pool granuloma" or skin lesions. Usually this cutaneous infection is localized around elbows, knees, or feet. Granulomata appear as a group of small papules which later coalesce to form a plaque, occasionally becoming pustular (18). The first cases of cutaneous infection or "cutaneous tuberculosis", developing in skin lesions exposed to the water in public pools, were noted by Hellerstrom (19). Outbreaks were also reported in Sweden (2), in the United States (21, 22) and in England (18, 23). The infection is usually benign and self-contained. Staphylococci which are frequently found in pool waters are also a known source of pyodermal infections in humans.

The role of swimming pools in the spread of foot infections has been well established; in most cases the causative agent is a fungus. Fungi have been more often isolated from the environment of the pool (walkways, pool decks, shower rooms) than from the water (24). Fungal infections associated with dermatophytes (Tinea pedis, or Tinea mentagrophytes) were noted in 1957 by Gentles and Holmes (25) and more recently by Gentles and Evans (26). Other species of fungi, specifically Epidermophyton and Trichophyton (24), seem to be the agents responsible for "athlete's foot". On the other hand, the papilloma virus is associated with "plantar warts" (24). Proper pool maintenance is important in controlling the transmission of these types of infection.

(c) Enteric and other infections

In general, the role of swimming-pool water in venereal and enteric disease transmission reflects more speculation than evidence. Manheimer (1) suggested in 1914 the possibility that gonorrhoeal vulvovaginitis was transmitted by swimming-pool water, though he did not exclude the possibility of transfer through the use of communal towels. Batten (27) also suggested in the early 1900's that poliomyelitis could be transmitted by swimming pool water. Enteroviruses were recovered from 3 of 4 wading pools at Albany, New York State, U.S.A. (28) during the summer of 1959. The presence of these viruses must be considered as a potential health hazard. In addition, many viral infections have been reported to environmental protection agencies without being listed in the scientific literature because the specific viruses responsible were not identified (P. Payment, personal communication). More recently, Dragas (29) has demonstrated the presence of some enteropathogenic strains of E. coli in swimming pools. These comprised

as many as 11 % of the total E. coli isolated from the water. These organisms are well known as a cause of acute enteric disease of children and adults but no case has been epidemiologically linked to the use of swimming pools.

Less common diseases may be found in the literature. Leptospirosis (30) has been associated with outdoor stagnant pools to which dogs and other animals had access. In these cases, the animals were probably responsible for the contamination of the water. In Czechoslovakia, between 1962 and 1965, 16 young people died of acute amoebic meningoencephalitis (31) after bathing in an indoor pool. Anderson and Jamieson (32) described another case of this disease in which the amoeba (Naegleria fowleri), had survived chlorination of the swimming-pool water. Finally, the transfer of helminth ova in swimming pools has been suggested by Müller (33), but epidemiologic proof is lacking.

It is apparent that swimming pools are occasionally associated with certain illnesses. There is a "general impression" that diseases of the ear, nose, throat, and skin are prevalent among users of swimming pools. In addition to estimating the spectrum and the causative agents of disease, it is necessary to find out the source and route of entry of the organisms in order to adopt preventive measures to reduce the risk of health hazards.

SOURCES OF POLLUTION IN SWIMMING POOLS AND REMEDIAL ACTION

Sources of pollution

Although there has been only limited epidemiologic evidence directly relating disease to swimming, the possibility is always present. The primary source of contamination to which a person swimming in a pool will be exposed is the other swimmers; the second source arises from improper operation of the swimming pool; the third source is more common in outdoor swimming pools and includes rains, soil washings, dust and animal wastes.

(a) The other swimmers

The requirement that a shower be taken before swimmers enter a pool is intended to reduce the amount of microbial pollution. Bathing and showering remove some microorganisms from the body surface but do little to change the microbial population of the body cavities. Moreover, as McLean (34) pointed out, while swimming the bather flushes his mouth and nose with pool water and discharges the waste water into the environment. Microbes and viruses may be also excreted by sneezing, coughing, and blowing which release organisms from the upper respiratory tract (mouth, nose, throat) in droplets of saliva or of nasal mucus. At a given moment, these discharges may be points of high pollution. As Amies (35) and Mallman (36) have shown, pollution becomes concentrated in pockets on the water's surface. As bathers are constantly creating new areas of pollution, and adjacent bather could ingest or draw in this pollution into his cavities before the organisms could disperse or be exposed to the action of disinfectants. The infective agents may also be introduced into the body through a breach of the skin surface. This may occur by simple contact or through a wound.

The microflora of a healthy body varies from person to person. Thus, human pathogens may or may not be present in a given individual. Organisms of the normal flora are basically non-pathogenic, harmless commensals. Under certain conditions, however, they may produce disease; for example, if there is an alteration in their environment, or if they penetrate a site different from their normal habitat. Among inhabitants of the skin, several types of gram-positive cocci (staphylococci, streptococci, sarcina) are ubiquitous (37). A number of diphtheroids (Corynebacterium) are located in moist areas. The gram-negative bacteria (Pseudomonas, Acinetobacter) are also confined to the moist areas, and some fungi and yeast occur in the skin-folds. The predominant organism of the oral flora is Streptococcus viridans which colonizes the buccal cavity and the upper respiratory tract; streptococci, staphylococci, neisseriae,

and mycoplasmata are also present in the upper respiratory tract (38, 39). The normal flora of the nose and of the eyes consists of corynebacteria, staphylococci, and streptococci (38). Escherichia coli is one of the most predominant residents of the intestinal tracts in adults and is the most readily detectable by available technology. Other organisms frequently encountered at this site include: clostridia, staphylococci, Streptococcus faecalis, Proteus, and Pseudomonas (38).

A survey of the literature has indicated that among the microorganisms of the normal body flora, cocci are the organisms most often shed into pool water. Robinton and Wood (40) have shown that the major types of bacteria shed by a swimmer and detected in filtered water without residual disinfection (i.e., with no chlorine added) were members of the genus Staphylococcus, and that S. aureus was consistently present. The faecal organisms (coliforms and Streptococcus faecalis) were also present, but they represented only a small fraction of the total viable bacteria discharged into pool water. There is strong evidence that, in chlorinated swimming-pool water, cocci are more resistant to chlorine than the coliform bacteria (41). The microorganisms most apt to survive are Streptococcus salivarius (41) and Staphylococcus aureus (42, 43).

(b) The improper maintenance of swimming-pool water quality

The problem of bacteria in pool environments is minimized when proper maintenance procedures are followed. Several operations may be improperly done or improperly supervised, e.g., maintenance of the chemical disinfectant and pH in the water, filtration and the recirculation of the water, diversion to waste of sufficient water and its replacement with fresh water, disinfection and cleansing of the environment of the pool, use of the shower by the bathers, and control of the bather-load.

Various viruses and bacteria have been found in pool waters where an adequate concentration of halogens was not maintained. Enterovirus (44), coxsackie, and parainfluenza viruses (45) have been isolated from such waters. Coliforms, staphylococci, streptococci, and Pseudomonas aeruginosa are the bacteria reported most often from waters with a low free chlorine residual (46, 47). The presence of these organisms, especially in wading pools, is attributed to inadequate recirculation of water throughout the pool or none at all (48). McLean et al. (48) attributed the non-recovery of viruses from pool water, after the addition of a small amount of virus when chlorine was absent, to the effects of dilution and dispersion by water movement. Where there was no water replacement, McLean et al. (48) also found an accumulation of coliform bacteria, despite water filtration before recirculation and a high

level of free residual chlorine. The presence of the bacteria was correlated with increased human pollution (ammonia, organic, and nitrate nitrogen). These solutes reduce the bactericidal properties of chlorine (49).

The bather-loading factor is also of prime importance. It is obvious that with more bathers, more pollution will be discharged from their noses, mouths, and skins. Urine, which may also contain microorganisms, is frequently voided in pools. Human defaecation can also occur, especially when children or retarded persons use pools. In 1941, Tapley et al. (50) noted a fluctuation of Neisseria catarrhalis with the number of people in the pool. Favero et al. (51) showed that when many were swimming, the number of bacteria and especially the number of staphylococci was also high.

(c) Environmental sources of pollution in outdoor swimming pools

Stormwater is one of the main causes of deterioration in quality of recreational water; it may also be a source of intermittent pollution of outdoor swimming pools. In the urban community, stormwater contains faecal contamination derived from faeces deposited on soil by cats, dogs, and rodents (52) or washed out of vegetation by rain (53, 54). Usually, in stormwater samples there are more faecal streptococci than coliforms (55). Occasionally, pathogens (Salmonella) have been detected (56, 57), as well as Pseudomonas aeruginosa (57, 58), a frequent inhabitant of soil and occasionally of plants (58, 59). In rural communities, stormwater can be a serious problem, because of the many animals (56). Defaecation and urination by birds, animals, and insects increase pollution of outdoor pool water (60). Also, dust (sand, ash, soil, and fragments of vegetation, pollen, seeds, etc.) laden with a variety of microorganisms could settle in pool waters and create new pockets of contamination (61). These sources of contamination increase the organic matter content. Both organic matter and sunlight reduce the effectiveness of chlorination. It is possible either to eliminate or at least reduce some of these health hazards and provide a safe environment for swimmers.

Remedial action

A clean pool is usually a safe pool. The owner is responsible for maintaining and protecting the health and comfort of bathers. The prime concern is to protect them from the microbiological agents previously described, thus preventing or minimizing disease transmission from one bather to another. Water quality should be maintained at a high level with chemical disinfectants, by recirculating water only after filtration, and by replacing part of it with fresh water. The function of water replacement is to remove ammonia, and albuminoid and organic nitrogenous compounds derived from the bathers. These compounds reduce the

bactericidal and the viricidal activity of some disinfectants. The pool environment (shower rooms, walkways, pool decks, etc.) should be cleaned and disinfected carefully to prevent the spread of foot infections.

The public also needs to be informed. Departments of Health, the Red Cross, schools, and similar agencies should strive for increased public education in aquatic safety and hygiene, and should explain the need for personal rules of hygiene with placards and advertisements. These include the use of sanitary conveniences before taking a cleansing shower with warm water and soap, discouraging such actions as blowing the nose, coughing, etc., and refusing admission to the pool to anyone having a cold, a skin disease, a sore eye or a sore throat.

The factors involved in general sanitation are complex, thus control and adequate supervision should be assigned to a competent and responsible operator with demonstrated knowledge of pool conditions and environment. Black et al. (46) reported that of the 193 pools that they examined in the U.S.A., 106 failed to maintain the standards required. In many cases, pool operators knew nothing about free residual chlorine and pH, and monthly reports to the Health Department were frequently completed in advance. There is no reason to believe that the situation is better in Canada.

INDICATORS USED OR SUGGESTED TO TEST BACTERIOLOGICAL QUALITY OF WATER IN SWIMMING POOLS

The use of coliform counts as an indicator of faecal contamination is almost as old as water bacteriology. The first edition of Standard Methods of Water Analysis* in 1905 already recommended Bacillus coli as an indicator of the bacteriological condition of water supplies. Enteric bacteria continue to be the accepted criterion for the sanitary quality of swimming-pool water, although there have been several suggestions that coliform organisms are not the best indicator. They do not provide the most satisfactory information with which to evaluate the bacterial quality of chlorinated swimming-pool water (62-64). Without discarding the conventional tests, new tentative procedures have been added. For instance, the latest (14th) edition of Standard Methods for the Examination of Water and Wastewater (65) suggests that microbiological testing include: total viable bacterial density, total number of staphylococci, total coliform density, number of Staphylococcus aureus and Pseudomonas aeruginosa.

Total and faecal coliforms

(a) Definitions

The 14th edition of Standard Methods (65) gives the following definitions of the total coliform group: all aerobic and facultative anaerobic gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35⁰C; all the aerobic, gram-negative, nonspore-forming, rod-shaped bacteria that produce a dark colony with a metallic sheen within 24 hours on an Endo-type medium containing lactose. The group comprises such organisms as E. coli, Enterobacter aerogenes, and Klebsiella pneumoniae.

Standard Methods give no clear definition for the faecal group. The separation of the coliform group by faecal or non-faecal origin has been based on a technical procedure (65). The faecal coliform group may be defined as all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation within 24 hours at 44.5⁰C. Non-faecal coliforms ferment lactose with gas formation at 35⁰C but not at 44.5⁰C.

* The title was changed to Standard Methods for the Examination of Water and Wastewater. Both are referred to as Standard Methods.

None of these definitions eliminate the genus Aeromonas; thus, some species of this genus react as E. coli. The positive oxidase test would serve to differentiate the genus Aeromonas from the E. coli group.

(b) Methodology

Two standard methods are available for coliform determinations: the multiple tube fermentation procedure and the membrane filter technique.

- i) Multiple tube fermentation (65): Tubes of lactose medium are inoculated with tenfold dilutions of the water sample to be tested (5 tubes per dilution). The presence of gas after 48 hours' incubation at 35⁰C constitutes a positive. A formula based on the numbers of positive and negative tubes provides an index of pollution, which is usually expressed as "the most probable number" (MPN) of coliform bacteria per 100 mL of sample. This number is not an actual count of bacteria but rather a statistical estimate of the number of bacteria that would give the observed result more frequently than any others. The same procedure is used for faecal coliforms; the presence of gas after 24 hours at 44.5⁰C affirms their presence.
- ii) Membrane filter procedure: Since the 13th edition of Standard Methods (66), the membrane filter (MF) has been accepted as an alternate method for the enumeration of total and faecal coliforms. The initial attempt to use an artificial membrane of nitrocellulose as a tool in bacteriology was reported in 1916. However, the use of the MF technique for the bacteriological examination of water only became widespread in the 1950's (67-69).

In this procedure, the water is passed through a filter that retains bacteria and the filter is placed on the surface of an appropriate medium. After 24 hours of incubation the coliforms or the faecal coliforms are counted. The advantages of MF procedures which include rapidity, ease of testing, and reduction of space, labour, and equipment, have been recognized and appreciated. The technique permits the examination of large volumes of samples taken directly from the field. However, over the past years conflicting reports on this methodology have appeared in the literature. Studies have shown the variability of MF procedures in the recovery of indicator organisms from water and wastewater (70-72). For instance, with this method, Brown (73) and later Hufham (74) showed that densities of E. coli varied between 20 to 80 % and 10 to 60 % respectively

of those determined by means of total bacteria counts (m-plate count broth). McKee et al. (75) in 1958, Lin in 1973 (76), Green et al. (77) and Bissonnette et al. in 1977 (78) found that the multiple tube fermentation technique gave better recoveries than the MF technique. It has been reported that a significant proportion of bacterial cells, especially those for which the intestine is the natural habitat, became physiologically injured in natural or chlorinated waters (79-80). Maxcy (81) suggested that nonlethally injured coliform bacteria are unable to grow and produce colonies on selective media. Later, Lin (76) reported that the broth medium of the MPN test provides a more favourable environment than the MF surface for the repair of the nonlethally injured cells. The discrepancy between results obtained with different brands of filter has been attributed to the structural conformation of the filter membrane (82, 83). Sladek et al. (83) indicated that a better bacterial recovery was obtained by using a membrane with a large surface pore size which cradles organisms within the pore and submerges them in available nutrients. The bacteria are thus protected from surface evaporation. Stevens et al. (84) and Green et al. (77) improved the recovery of the faecal coliform with the MF method by short-term incubation on a selective medium at lower temperature before the incubation at 44.5°C. At present it appears, as Tobin and Dutka (85) conclude, that there is "a great need for standardization of membrane filters, since the majority of users and purchasers believe that all membrane filters are equivalent". Until this is done, the U.S. Environmental Protection Agency (86) has suggested the multiple tube test as the method of choice for faecal coliform determination on effluents containing chlorine.

Other indicators

The use of coliforms as a sanitary indicator for swimming-pool water has been challenged over the past years by many workers, including Gilcreas (87), France and Fuller (88), Seligman (89), Mallmann (90) and Favero et al. (62). One reason is the lack of evidence that enteric diseases are contracted by users of swimming pools (except in a few isolated cases) which suggests that coliform standards are of little significance except as an index of the effectiveness of disinfection. Considerable interest has been aroused by the organisms discharged by bathers that are involved in diseases affecting the swimmer's nose, eyes, mouth, ear, throat, or skin; these diseases represent more than 50 % of the infections encountered in swimming pools.

(a) Enterococci: Staphylococci and Streptococci

A "coccus" index of less than 15 organisms per 100 mL was proposed by Seligman in 1951 (89) as a standard of safety. The index was measured by the MPN method with azide dextrose broth. Among the organisms present in the positive tubes, he found the genus Staphylococcus (S. epidermidis), Streptococcus (S. mitis), S. salivarius, S. faecalis. Ritter and Treece (91) showed that Staphylococcus aureus and Streptococcus salivarius were 5 to 20 times more resistant to chlorine than the coliform bacteria. Mood (92) found that in pool water streptococci were more resistant to a residual free chlorine than coliforms. Favero et al. (62) established that when intestinal bacteria were present in pool waters, staphylococci and streptococci were also present in large numbers. However, they also noticed that staphylococci were frequently isolated when no coliform bacteria or enterococci were found, and when the total count was low. These authors proposed staphylococci as an indicator of pollution in pool waters and stipulated that the index should be less than 100 staphylococci per 100 mL. But Keirn and Putman (93) felt that this limit was too high; they thought that 30 staphylococci per 100 mL might be a more realistic limit. Robinton and Mood (94) have demonstrated that members of the genus Staphylococcus are shed by swimmers in large numbers; under different conditions they were able to isolate S. aureus from pool water. They therefore concluded that this genus would be a good index of water contamination. Surprisingly, in the last (14th) edition of Standard Methods (65), the tests for staphylococci have not been routinely included for the examination of swimming-pool water, because of the lack of data "documenting their accuracy, selectivity, specificity, sensitivity and precision". Streptococcus salivarius has also been suggested by a few authors as an indicator of pollution in swimming pools. However, this organism did not appear to be a good index, since it was not always recovered from samples (62, 94) and it was not shed constantly by swimmers (94).

(b) Pseudomonas aeruginosa

This bacterium is well-known to be a potential pathogen. At times, human and animal faeces contain this agent. Soil is also a reservoir of Pseudomonas aeruginosa and sometimes this bacterium can colonize plants (95). It has frequently been isolated from infected skin or ears, especially among swimmers (64, 96, 97). It is also considered to be one of the most frequent causative agents of hospital-associated infections (98, 99). The presence of this organism in swimming-pool water has been reported by several investigators (62, 64, 100, 101). Pseudomonas can survive chlorination of pool waters (102, 103) and it may be found in the absence of coliforms or faecal coliforms (101). In cases in which the absence of indicator bacteria may give a false sense of security, it has been suggested that Pseudomonas aeruginosa should be included in the bacteriological evaluation of water quality (90). There have been

many attempts to make selective media for the isolation of P. aeruginosa (104). Membrane filter and multiple tube techniques (65) have also been used.

However, when a large number of P. aeruginosa were present, it was difficult to distinguish between pigmented (soluble diffused pigment) and non-pigmented colonies on membrane filters.

More extensive studies are needed to establish the prevalence of Pseudomonas aeruginosa in swimming-pool water and the relationship between organism density and human health.

(c) Total viable bacteria or standard plate count

The standard plate count gives an index of the total viable heterotrophic population in water. However, this estimation is empirical because no single medium, temperature, or incubation time will recover all the organisms present in water (62, 105). The 14th Edition of Standard Methods (65) proposed a relatively rich medium (tryptone 5.0 g, yeast extract 2.5 g, glucose 1.0 g per litre) for the enumeration of the total microflora. It has been shown that such a medium can inhibit the growth of organisms from relatively clean water (105, 106). On the other hand, several authors (106, 107) have demonstrated that the recovery of faecal organisms was better on rich media, which allow the repair of the injured cells. Thus, the interpretation of enumerative results must be made cautiously. A high total count may indicate a deficiency in the treatment process, but it is not a true indicator of the potential pathogens. For example, Favero et al. (62) have shown that in iodinated swimming pools, the total population of organisms was between 3000 to 10 000 per mL, but 99 % of these consisted of the apparently harmless saprophytes Alcaligenes faecalis and Pseudomonas alcaligenes.

The above considerations indicate that the present standards used to determine the quality of swimming-pool water, based on the presence of coliforms and total count, are inadequate. These two parameters must not be used alone. Additional information should include the chlorine residual level.

(d) Utilization of chlorine residual determinations as an indicator

In 1969 the Bureau of Water Hygiene in the U.S.A. conducted a national community water supply survey (CWSS) on 969 water systems serving about 18.2 million people. It was found that in most cases insufficient samples for bacteriological analysis were taken (108). Since these analyses were expensive in time, cost, and personnel, the Bureau concluded that a more practical technique must be developed. It suggested that all systems must be chlorinated,

so that the determination of residual chlorine might be a more practical way to monitor health hazards. The maintenance of good bacteriological quality (less than 1 total coliform per mL) is dependent on keeping chlorine present continuously throughout the system (109). The loss of residual chlorine may serve as an indicator that foreign material has entered the system (110); or it may also signify that there is a breakdown in the treatment process. This latter is responsible for most disease outbreaks (111). The absence of sufficient free available chlorine may in itself be considered a public health hazard. Thus, tests for it should be routinely performed on pool waters which are mainly disinfected by chlorine (112). However, the presence of free chlorine residuals does not guarantee the complete absence of bacteria or viruses, as we will see in the next section; thus some bacteriological analysis should also be continued, and one method of testing should not be substituted for the other.

TREATMENT APPLIED TO SWIMMING-POOL WATERS

The treatment of pool waters has two main objectives. One is to maintain adequate clarity of the water by filtration; the other is the removal of pathogens through proper disinfection.

Filtration

Water is filtered to remove colloidal and solid particles. The main reason for this is to eliminate safety hazards inherent in turbid water. A lifeguard or a swimmer must be able to see or distinguish another person in distress. Also, a swimmer needs to see quite well when he is under water. The present standards state that the water of a swimming pool shall be clear enough to enable a disc of about 15 cm diameter placed at the deepest point in the pool to be visible to an observer standing on the deck, approximately 10 m away from the disc. A second reason for providing clear water is to make disinfection more effective. Hudson (113) has cited a number of examples in which turbidity reduction has paralleled reductions of bacteria and viruses. Sanderson and Kelly (114) have also shown that coliforms were always present in chlorinated water if the turbidity was between 4 and 84 "turbidity units" (TU). Bacteria seem to be embedded or absorbed by the solid particles and therefore not in contact with the disinfectant. Filtration removes nematodes or protozoa which may ingest bacterial pathogens so that the latter are completely protected against chlorination (115). The practice of filtration is also based on aesthetics. Koertge (116) reported that swimmers refused to swim in a pool when the water was noticeably turbid. Turbid water does not look attractive; it appears unsanitary, and may in fact be a potential health hazard.

Sand and diatomaceous filters are the types commonly used in swimming pools. Filtration can be achieved by gravity, vacuum, or pressure. Two main classes of sand filter exist, the conventional rapid sand filter and the high rate filter. The diatomaceous earth filter is made of siliceous fossils which are the remains of microscopic marine diatoms. A joint study (117) concluded that diatomaceous earth filters were at least as effective as conventional rapid sand filters and sometimes more effective. Jackson (118) confirmed the superiority of diatomaceous earth filters in maintaining adequate clarity in pool waters. However, Koertge (116) found that pools equipped with conventional rapid sand filters have a lower turbidity than pools equipped with diatomite filters. Since the differences are slight, it appears that

both procedures, if run properly, can provide pool water of good clarity. High rate sand filters are somewhat inferior in their ability to remove suspended colloids, which may impair water quality, until the colloids are precipitated by flocculating the pool with aluminium sulphate (filter alum).

The more recently developed cartridge filter approaches the efficiency of conventional rapid sand and diatomaceous earth filters.

Disinfection

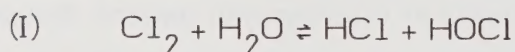
The term disinfection is used to describe a process that kills or removes all organisms capable of producing infection. Disinfected water is not necessarily sterile: sterilization means that all forms of life have been destroyed (119). Disinfection is accomplished by a variety of techniques. These include: halogenation (chlorine, iodine, bromine), ozone treatment, radiation (ultraviolet), and the oligodynamic action of silver.

Historically, chlorine has been the method of choice for disinfecting water supplies (120). From the early 1900's to the present, it has retained its popularity, although recently this has been seriously challenged. The persistence of waterborne disease outbreaks, the demonstration that viruses are extremely resistant to chlorine, and the discovery that chlorination of water can lead to the formation of compounds, some of them known or suspected carcinogens (121), have all caused a re-evaluation of chlorination and a consideration of new disinfection techniques. At present, however, swimming-pool waters are mainly disinfected by chlorination.

(a) Chlorine

i) Chemistry and methodology

Chlorine is applied to water as chlorine gas or hypochlorite. In pure water, chlorine rapidly forms hydrochloric acid and hypochlorous acid (I). The hypochlorous acid then partially dissociates to give hydrogen ions and hypochlorite ions (II) (120).



The three forms of free available chlorine (Cl_2 , OCl^- , $HOCl$) exist together in equilibrium. Their relative concentrations are determined by the pH value, the temperature, and the dissolved solids (120).

Natural or potable waters contain impurities such as ammonia or organic compounds which can react with chlorine. The chief source of these impurities in pool waters is the bather himself, who discharges ammonia and organic nitrogen into the water

in perspiration and urine. Chlorine, especially as hypochlorous acid, reacts with ammonia and organic nitrogen compounds to form chloramines (mono-chloramine, NH_2Cl , dichloramine, NHCl_2 , or nitrogen trichloride, NCl_3). At the normal pH of drinking and pool waters (about 7.4), the product of the reaction is almost entirely monochloramine. These inorganic or organic chloramines make up the combined chlorine residual. The free available chlorine (FAC) residual is defined as the sum of hypochlorous acid and hypochlorite ion. Free and combined available chlorine together make up the total chlorine residual in water (122).

As chlorine is subject to destruction by the ultraviolet rays of sunlight, various residual chlorine stabilizers have been introduced. Since 1955 cyanuric acid and cyanurate have been used in many outdoor swimming pools to reduce the rate of the photochemical reaction of chlorine. These compounds form a loose bond with free chlorine. The resulting combined chlorine is more stable and more resistant to ultraviolet radiation than free chlorine (123).

In practice, it has been found that the FAC residual should be significantly higher than the combined chlorine residual (75-85 % of the total chlorine residual) because free chlorine is a better disinfectant and algicide (120, 124). The differentiation between the free and the combined residual is required for determination of pool water quality. Equipment for continuous process analyses capable of differentiating between these two species is now available (125, 126), but its high cost necessitates the use of an alternative procedure, the test kit, for swimming pools. The advantage of test kits are portability, simplicity, and low cost. The disadvantages are that accuracy, precision, and specificity are all questionable. In a recent study in 1974, Guter et al. (127) evaluated five commercial test kit procedures. Their results indicate that the syringaldazine (liquid) procedure is the only test that exhibits absolute specificity for the FAC. It was not as accurate and precise as N, N-diethyl-p-phenylene diamine (DPD) over a range of temperature and pH, but with the DPD procedure it was not possible to eliminate interference by monochloramine (127). Modifications of these procedures are under investigation (128, 129). In practice, these test methods do provide reasonably accurate and precise results for routine control purposes (129) if they are carefully used.

ii) Dose and effectiveness of chlorine in disinfection

There is strong evidence that the susceptibility to chlorine varies among structurally different organisms and even among the same group of organisms. Chang

(130) classified pathogens in a decreasing order of resistance to destruction as follows: bacterial spores, protozoan cysts, viruses, and vegetative bacteria. He stated that cysts are about 160 times as resistant as E. coli and 9 times as resistant as the hardier enteroviruses to hypochlorous acid. Scarpino et al. (131) showed that viruses required 175 times the FAC required by coliforms for 99 % inactivation. Krusé et al. (132) found the same kind of results with chloramine. Among bacteria, chlorine levels which eliminate coliforms will also eliminate Salmonella and Shigella, but it has been shown that Staphylococcus aureus, Streptococcus salivarius, and the enterococci were 5 to 20 times more resistant to chlorine than the coliforms (133, 134). Robinton et al. (135) stated that with a FAC of 1.0 mg/L or above not more than 5 staphylococci per 100 mL will be present.

Further problems arise from the fact that different chlorine species differ in their ability to disinfect water. The most effective germicidal form of chlorine is hypochlorous acid (HOCl) (136, 137). For instance, it has been estimated that E. coli is killed 60 to 70 times faster with HOCl than with OCl^- . Chloramines are even less effective, acting on E. coli 270 times slower than HOCl (138). It has been stated that the presence of as little as 0.05 mg of ammonia nitrogen per litre of water will increase from 0.25 to 20 minutes the time necessary for 99.9 % killing of bacteria by chlorine (139). Ortenzio and Stuart (140) pointed out that nitrogen from urea has no measurable effect. Several investigators have also established that when chlorine is stabilized with cyanuric acid, longer exposure or more chlorine is required to kill bacteria than if HOCl is used alone (141). Results of field investigations on this subject are contradictory: sometimes these compounds inhibited the action of chlorine (123) at concentrations greater than 100 mg/L, but potentiated it at lower concentrations (142).

Field evaluation of the bactericidal action of chlorine in swimming pools is more difficult because of such uncontrollable variables as the number of bathers, efficiency of filtration, and quantity of contaminants. Early chlorination practice consisted of the application of the minimum amount (0.25 mg/L to 0.05 mg/L) needed to ensure the maximum bacterial kill. At that time public opinion was against chlorination and equated it with bad-tasting water (120). The first pools in the United States to use high free residual chlorination (1.0 to 1.5 mg/L) did so in 1949 (143). That procedure was also recommended by the Ministry of Health in England in 1950 (144). Brown et al. (145) suggested that a free chlorine residual of 0.1 mg/L could be adequate to maintain bacteriological purity of water in swimming pools;

however, they recommended a level of 0.5 mg/L since the inactivation of 3 different types of polioviruses required this concentration. Kabler et al. (146) found similar results with 2 other virulent polioviruses. Black et al. (147) reported an alarming frequency of P. aeruginosa isolations in pool water with an FAC residual of less than 0.3 mg/L. The same frequency of occurrence was also listed for the coliforms, and staphylococci. Thus, among the pools with 0.3 mg/L of FAC or more, 82 % contained no coliform, while in swimming pools with less than 0.3 mg/L of FAC this figure dropped to 48 %. Mallmann (148) demonstrated the absence of coliform in pool waters with an FAC of 0.5 mg/L; only a small number of cocci (less than 16 per 100 mL) were present. Various workers have established that the continuous maintenance of an FAC residual of 1 mg per litre or above will provide adequate disinfection of water. In the United States it is also common practice to utilize superchlorination (5.0 to 10.0 mg/L). Where there are many bathers this is usually carried out weekly, on days when the pool is not in use (120).

Finally, it is necessary to evaluate and summarize the practical significance of certain factors on the bactericidal properties of chlorine in pool waters. First, a proper chemical balance should be maintained at all times. The pH range should be between 7.2 and 8.0 and the alkalinity between 100 and 150 ppm as CaCO_3 (120). The temperature of the water being chlorinated has some effect on the reaction rate of chlorine with ammonia nitrogen (124), and consequently on the germicidal power of the applied chlorine. Bauman and Ludwig (149) showed a ten-fold reduction in germicidal efficiency for a water temperature change of about 25 degrees Celcius. Also, the level of ammonia nitrogen should not exceed 0.4 mg/L; otherwise, it will provide nutrients sufficient for algal and bacterial growth. The amount of ammonia present in pool waters has been reported to vary from less than measurable amounts to as high as 1.0 mg/L (139, 150). If cyanuric acid is used to stabilize chlorine, concentrations of the former in the range of 20 to 25 mg/L are suggested; accurate pH control and bacteriological examinations are also recommended (123). The use of algicides should be avoided as the decomposition products of the various quaternary ammonium compounds used to control algae in pool waters can combine with the free chlorine to form undesirable chloramines (151).

(b) Other methods of disinfection

i) Bromine

This compound has been utilized on a limited scale as a pool water germicide (152). Bromine is added to the water either as liquid bromine or more commonly as "bromine

sticks" (N-chloro-N-bromo dimethyl hydantoin). Bromine reacts with water to form hypobromous acid (HOBr) which is the predominant species if the pH is less than 8.7; when ammonia is present, bromamines are formed. Hypobromous acid is extremely effective against bacteria, viruses, and protozoan cysts (153). The germicidal activity of the bromamines is superior to chloramines, at least in pool waters (154). Brown et al. (152) reported only slight bacterial contamination when the bromine residual was maintained above 2 mg/L.

ii) Iodine

Studies have also been conducted to determine the effectiveness of iodine as a pool water disinfectant. In water iodine exists essentially as molecular I_2 and hypoiodous acid (HIO or H_2OI^+). Iodine does not form iodamines with ammonia. Favero and Drake (155) have shown that pool waters treated with iodine contained fewer staphylococci than those which were chlorinated. Keirn and Putman (156) stated that staphylococci appear "more effectively controlled" by iodine than by chlorine. The effectiveness of both compounds is similar on coliform bacteria and streptococci. Chang and Morris (157) demonstrated the superiority of iodine over chlorine in killing the cysts of Entamoeba histolytica. Marshall et al. reported that a low iodine treatment (0.2 to 0.8 mg/L free iodine) provided satisfactory water and that high iodine treatment (0.9 to 2 mg/L) provided almost a sterile pool but irritated the eyes (158). It has been shown that in doses up to 1.0 mg/L iodine produces no colour, taste, or odour in water (159). The U.S. Public Health Service has tentatively approved the use of iodine for pool disinfection provided the total iodine content in all forms does not exceed 5 mg/L. The advantages of iodine are that it remains in its active molecular form over the usual pH range of swimming-pool water and persists longer than either bromine or chlorine. Its major disadvantage is its high cost.

iii) Ozone (O_3)

Ozone is a gas, and it is often referred to as an allotrope of oxygen. It is produced on-site by electrical discharges in oxygen gas. The use of this compound in water treatment is well established, and it has been used for this purpose for over 70 years in Europe (160). According to Bringman (161) ozone destroys bacteria 600 to 3000 times more rapidly than chlorine. Poynter et al. (162) demonstrated that E. coli was more susceptible to ozone than poliovirus. Kessel et al. (163) have shown that polioviruses were more rapidly inactivated by ozone than by chlorine; however, clumping of viruses reduced efficiency of disinfection. In practice an

ozone residual of 0.1 to 0.2 mg/L should kill bacteria, and 0.4 mg/L should inactivate viruses. Ozone is also used for food preservation, and for the treatment of water used in zoos, medical baths, and swimming pools (160). Poynter et al. (162) pointed out that equivalent turbidity to "5 mg/L" and less does not affect ozone efficiency; that it is stable for a short period of time and breaks down to form free oxygen. An increase in temperature decreases its solubility. At the present time, little is known about the health effects of compounds produced by the action of ozone on organic matter.

Conclusions

Among the procedures used for the disinfection of water, only the ones employed in pool-water treatment have been reviewed. A new technology using silver ion as a bactericide has not been discussed because of lack of data (164). At the present time, chlorine is still one of the best practical disinfectants; however, the formation of trihalomethanes during the chlorination in drinking-water treatment is of some concern, though the health significance of such compounds has not yet been completely evaluated. Among the different solutions, one would be the removal of organic compounds before chlorination is applied. Another could be the replacement of chlorination by another procedure. At present, ozone shows great promise in the process of disinfection of water, but only as a complementary agent for chlorine.

CURRENT STANDARDS REGULATING THE QUALITY OF SWIMMING-POOL WATERS IN CANADA

Although the provinces of Canada have public health programs concerning water quality standards, some provinces (Nova Scotia, New Brunswick, Prince Edward Island) do not have any specific regulations concerning swimming-pool waters. However, this will be corrected soon, since Nova Scotia and New Brunswick are presently drafting regulations. It is regrettable, however, that no defined directives exist at the national level, for it would seem that water quality in swimming pools should be the same across Canada. Obviously, responsibility for the control and implementation of such directives should be guaranteed by the provinces. Researchers should be encouraged to study swimming-pool waters, in order to provide epidemiological documentation and bacteriological data. Furthermore, it is impossible for us to determine the extent to which criteria demanded by the provinces are respected.

Definitions

The regulations described in this section are applicable to all public wading and swimming pools.

A public swimming pool is "any swimming pool generally available to the public or any segment of the public for their use" (165). This definition includes swimming pools at hotels, motels, summer camps, apartment buildings, condominiums, multiple housing units, mobile home parks, educational institutions, and private clubs as an additional facility for the use of the guests, tenants, or members.

A wading or paddling pool is defined as "a swimming pool used for wading by small children and having a maximum water depth not exceeding 24 inches" (165).

Non-permanent public pools have been created only in the Northwest Territories. They are "low-cost, plastic-lined pools which are intended to be used only until such time as they can be replaced by swimming pools of much better construction" (166). Residential pools are not governed by the regulations below. A residential pool has been defined as "a swimming pool created by artificial means located on private property under the control of the homeowner, the use of which is limited to swimming or bathing by members of his family or guests" (167).

Water supply and water treatment

It is recommended by all provinces that the water supply serving a public pool as well as its facilities (drinking fountains, lavatories, showers, etc.) shall be of potable quality complying with the standards and objectives of potable water in Canada (168). However, the Medical Officer of Health may approve the use of water from natural resources, including saline waters.

Most provinces specify that the water in the filled pool shall be sufficiently clear so that the pattern of the pool drain or a black disc can be readily visible at the deepest point of the pool by a person standing on the edge at a distance of about 10 m.

Every public swimming pool shall be provided with a circulating system, and the entire volume of the pool must be recirculated after filtration in 6 hours, thus providing a minimum turnover of 4 times per day (165, 166, 169-171), or in less than 8 hours (167, 172).

The pool water is continuously disinfected by chlorine compounds; in a few cases bromine or iodine are also permitted (167, 169, 170). The free available chlorine (FAC) level shall be between 0.5 mg/L and 1 mg/L at all times when the pool is used; at the same time the pH range shall be between 7.2 and 7.8. Some provinces (British Columbia, Ontario) accept the use of cyanurate as a chlorine stabilizer. Only one province (Ontario) states that the determination of the FAC residual shall be done half an hour before the bathers use the pool water and after that, every 2 hours or less, as long as the pool is in use. When required, the FAC residual is to be determined using a method not subject to interference by chloramine or other chlorinated organic compounds.

Bacteriological standards of pool water

It is surprising to find that in the regulations of all provinces, bacteriological standards receive the least attention and are least developed. Moreover, sometimes this factor is completely omitted (Ontario), or very vaguely defined (Newfoundland and Labrador).

The frequency of sampling varies enormously from one province to another. For instance, the samples are taken twice a week in Alberta and in the Yukon Territories, and only 2 to 4 times a year in the Northwest Territories and Prince Edward Island. Some provinces (British Columbia, Quebec, Saskatchewan) do not specify the sampling frequency. The existing regulations stipulate that the sample shall be collected "at a time when the pool is at a high bathing load" (167), at a "point near the outlet of the swimming pool and at such additional sampling points as may be selected to indicate the quality of the water being maintained throughout the swimming pool" (165).

The provinces that require microbiological determinations of coliform bacteria and of total viable bacteria use the methodology of the latest edition of Standard Methods for the Examination of Water and Wastewater (173). The total coliform shall be zero or not more "than 15 % of any series of samples, nor more than 2 consecutive samples in any series of samples, collected at a time when the swimming pool is in use, shall show the presence of bacteria of the coliform group in any of the five 10-millilitre portions examined, or contain more than 200 bacteria per millilitre when incubated for 24 hours on standard plate count at 37°C" (165). Quebec follows the suggestions made in the latest (14th) edition of Standard Methods (173): its microbiological testing requirements include total coliform bacteria, Staphylococcus aureus, faecal streptococci, and Pseudomonas aeruginosa, using membrane filters. None of these bacteria should be present in 100 mL of pool water.

All these regulations dealing with the operation and safety of a public swimming pool are subject to the surveillance of the Medical Officer of Health appointed under the Public Health Act for the area in which the pool is located. He may order changes or close a pool if the water quality or sanitation are not satisfactorily maintained.

RECOMMENDATIONS

The present current regulations for swimming pools in Canada place no emphasis on the bacteriological analysis of water. The levels of disinfectants and of pH that should be maintained are closely specified. However, we feel that because of the complex chemical interaction of disinfectants these alone are not sufficient to guarantee a water of acceptable sanitary quality. Thus, we make the following recommendations.

1. Disinfection and management of the water chemistry

Whatever chemicals are used, it is necessary to check their concentration before the bathers are admitted to the pool, and frequently (every 2 hours or less) during the time the pool is used.

Since chlorine will probably continue to be used extensively, it is necessary to maintain proper control of the free available chlorine residual (0.5 mg/L or more, which represents 75 to 80 percent of the total) and of the pH of the water.

The alkalinity of the pool should be checked and adjusted to fall in the range of 80 to 150 mg/L CaCO_3 if there is any difficulty in keeping the pH within 7.2 to 7.8 range.

The use of chemical compounds such as quaternary ammonium compounds (algicides), which are not compatible with chlorine, should be avoided.

In order to prevent the undue formation of chloramines and chlorinated organic compounds, periodic shock treatment by superchlorination (5 to 10 mg/L of chlorine) should be used. This should be done at intervals of one week to a month, depending on the bather load.

All pool water should be changed at least once a year.

If bromine is used, total bromine residual should be at least 2 mg/L. Kits are available for bromine determination, and sampling for bromine should be done as often as for chlorine. The brominated pools should be shock treated with chlorine in the same manner as chlorinated pools.

Other disinfectants should not be used for public swimming pools, unless they are accepted by provincial legislation.

2. Bacteriological Analysis

Bacteriological tests should be carried out at the discretion of the Medical Officer of Health. It is recommended that sampling be done in the late morning, after some use of the pool, but permitting time for laboratory analyses to be made the same day.

At present, there is a need to establish sampling procedures, and the number of samples that should be taken. It is suggested that a committee be set up to work out suggested uniform standards for sampling pools. This committee should also make recommendations on the procedures to be followed after gross fouling of pools.

A further recommendation is that field studies be carried out correlating counts of different microorganisms with bather load, pH, and chlorine levels of swimming pools. It would be better to do systematic studies on a few pools than superficial studies on many; most studies so far have been superficial. Both pools presenting problems and those without problems should be studied.

The present bacterial evaluations which include total coliform and total viable counts are inadequate and insufficient. The standards should also include presence or absence of Staphylococcus aureus, and Pseudomonas aeruginosa, total staphylococci and faecal streptococci. A pool which may be considered unsafe with a coliform count greater than 1 per 100 mL, should also be considered unsafe if any Staphylococcus aureus or any Pseudomonas aeruginosa are found in 100 mL of sample. In 90 % of all samples, the total staphylococci should be less than 25 per 100 mL, and should not exceed 100 per 100 mL in any one sample.

Since membrane filter methods give variable results, it is recommended that the multiple tube tests (MPN) be used whenever possible.

The operator should demonstrate a knowledge of practical pool water chemistry sufficient to motivate and enable him properly to manage and control the sanitary quality of the pool water.

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